Dynamic Strike Force Asset Reallocation
for Time Critical Targeting

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Abstract
This paper describes decision support tools that are being developed to support dynamic reallocation of tactical air assets in particular and the strike force assets in general. Tools that support situation awareness, risk assessment, and weapon-target paring options generation in an integrated architecture are discussed. Preliminary work is presented on each tool and its usage as a decision-aid component.

Introduction
The dynamic arena in which tactical air assets operate dictates the need for flexible targeting options generation in the event of significant changes in the environment or the introduction of high priority targets of opportunity. This need is compounded by the complexities introduced by the incorporation of advanced munitions and the requisite planning they require.

An automated force-level planning tool must provide automated flight planning and mission planning capabilities to the tasking authority. Requirements for an automated flight planning tool include automated routing, platform capabilities and performance data pulls, and weather forecasts. Aspects of an automated mission planning tool include the ability to coordinate disparate aircraft, sensor and weapon systems, deconflict routes, evaluate mission effectiveness and platform risk. In concert with the commander's intent, this tool should also support automated retasking and asset allocation.

The Real-time Execution Decision Support (REDS) program is developing automated force level decision aids that facilitate dynamic decision support. These decision tools are being developed under an integrated Decision Support Suite (DSS) that is referred to as the REDS-DSS effort.

Utilizing in-theater assets, REDS-DSS allows the tasking authority to respond to dynamically changing targeting situations. The near-term objective is to move an air-strike package *en mass* to nearby high-priority targets as well as react to changes in the environment. The long-term objective of this work is to provide a capability to retarget strike assets beyond the original strike area with the potential inclusion of joint and/or allied assets. The REDS-DSS tools will provide the warfighter with an increased ability to respond to changing battlefield and operational conditions while maintaining operational tempo. With this suite of tools, mission repair, replanning, and retargeting of in-theater assets may be achieved in response to high priority targets and intelligence updates.

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Situation Awareness

The cornerstone of rapid retargeting resides in assessing the common operational picture (COP). To achieve this objective, the REDS-DSS is incorporating data feeds from GCCS-M and TES and pulling forward the capabilities and performance data for the entities in the COP as well as any salient mission planning information that has been generated. A tool that has been termed SIREN for Sensors, Intelligence, ROEs, and Environment Network has been prototyped in an effort to meet this requirement. SIREN's objectives include:

- Monitoring the environment
- Assessing changes to the entities in the environment
- Identifying entities in the environment
- Retrieving entity capabilities and performance information
- Managing the prioritized target list

The Track Manager Server (TMS) and the Tactical Exploitation System (TES) are being incorporated to provide intelligence feeds. Additional intelligence is being pulled forward from the MIDB and Quiver databases. The track data is monitored and presented on both a map viewer and a Gantt chart as shown on the prototype screen in Figure 1. The SIREN tool aggregates capabilities and performance information with the corresponding track information and the mission planning data to provide comprehensive data objects that support dynamic asset allocation.

As new entities (or tracks) enter the region of interest, they appear on the Gantt timeline based on their time stamp (Time-in-COP). An alert window warns the users when new entities enter the COP. When the entity is no longer represented by a track, it leaves the COP (Time-out-COP) and the Gantt timeline ends. Trends can be readily visualized via the Gantt bars as entities become active and inactive within the COP.

A map viewer is provided as part of the SIREN user interface. The user can toggle the entities that she desires to monitor via a listing of entities in the COP and the Airplan. For example, an intelligence officer can display the enemy Order of Battle and keep the Watchstander abreast of any changes that effect the mission. Another example is that the Airboss can be alerted to the execution of the Airplan when entities under his purview enter the COP.

By integrating components from RADIANT GLASS, a user can toggle a capability that fades the entities in the map as a function of the latency of the data. In addition, the user can specify regions of interest such as no fly zones or air corridors that can be used to generate alerts should an entity enter, or leave, that particular region.

The prioritized target list is supported from the Joint Integrated Product Target List (JIPTL). These targets can be monitored in SIREN as desired by the user. By managing the prioritized target list, SIREN also facilitates the user entering other high priority targets into the target list. These targets may be targets of opportunity that are high priority and have narrow windows of opportunity.
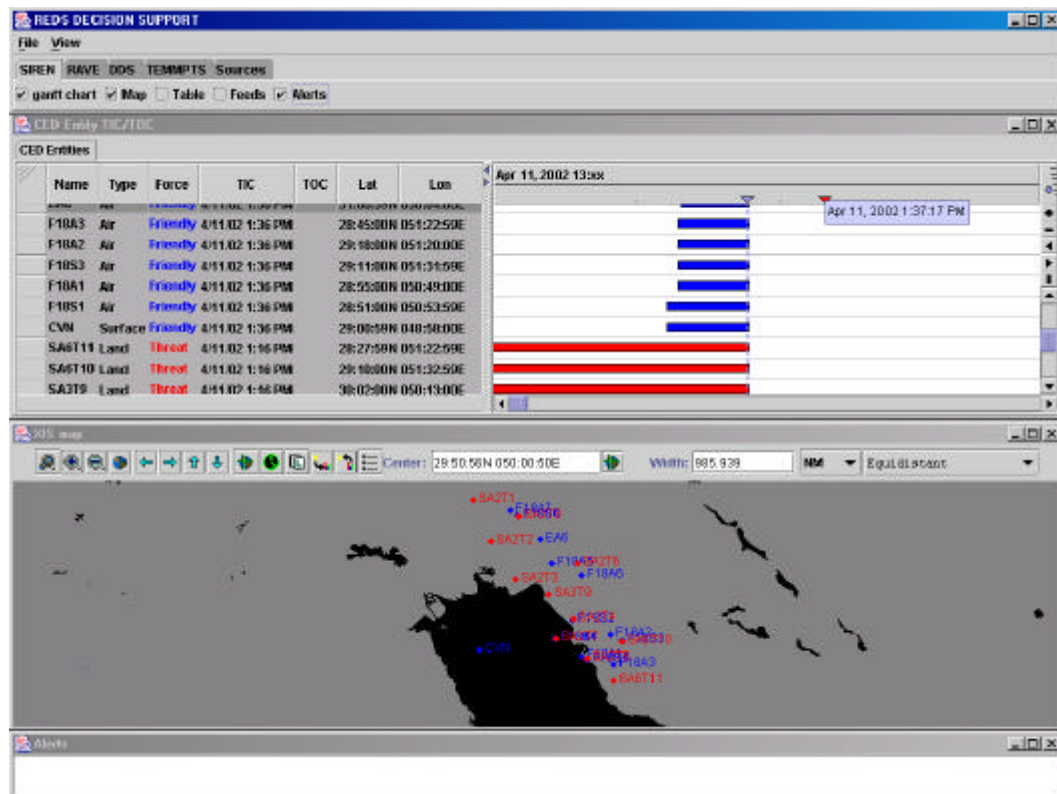
Figure 1. A prototype display showing SIREN capabilities for a simulated environment from a TMS feed.

Risk Assessment

The evolutionary threat arena requires the constant monitoring of threats to all blue force entities in the operational battlespace. This capability is paramount in triggering a dynamic retargeting event. A tool that has been termed RAVE (for Risk Assessment and Validation Engine) is currently under development. RAVE's capabilities include:

- Determining risk to entities in the COP
- Providing a risk-based trigger function to the dynamic retasking tool
- Validating threat capability based on situational information
- Providing a mechanism for displaying risk evaluations in real time
- Quantifying deconfliction as part of risk assessment

The methods implemented for ascertaining risk to a blue force entity is dependent on the entity type. A static entity can be evaluated based upon its current position and proximity to red forces and red force capabilities. A mobile entity must be evaluated based upon its planned route or perceived path.

For tactical aircraft, templates of the radar signature have been generated against various threats. These templates are used for determining the level of exposure that an aircraft has against a particular threat based upon the aircraft's orientation, altitude, and range from

the threat. The level of risk calculation is a function of the continuous time that an aircraft is within the threat's range and a function of continuous time that the aircraft is out of the threat's range. (Thus a route optimizer should seek to minimize the continuous time of exposure and maximize the continuous time of non-exposure to the threat.)

At the end of the kill-chain analysis, the mechanics for estimating the threat-based risk component to an airborne asset are relatively straightforward. First the route is decomposed based upon the waypoints, velocity of the platform, and maneuvers. The decomposed route is then evaluated to determine if the route points that are within threat range. The continuous time that a platform is within threat range can be integrated and compared with a risk-level threshold. When the platform is no longer within range, the risk level decays based upon the required time of continuous non-exposure to the threat to prevent tracking. Finally, the risk levels are normalized based on the risk threshold.

An example is given below in Figure 2 with a hypothetical route and a stationary template. In this example, the template does not change with respect to aircraft orientation, altitude or range. Figure 3 shows the results of evaluating the route through the threat region based upon kill-chain analysis. Figure 3(a) indicates when the aircraft is within range of the threat's radar. Figure 3(b) evaluates the continuous time of exposure relative to the risk threshold (shown by the dashed line). Figure 3(c) shows the normalized risk at each point along the route. For the current implementation, the l_∞ norm can be taken as the overall risk of the route.
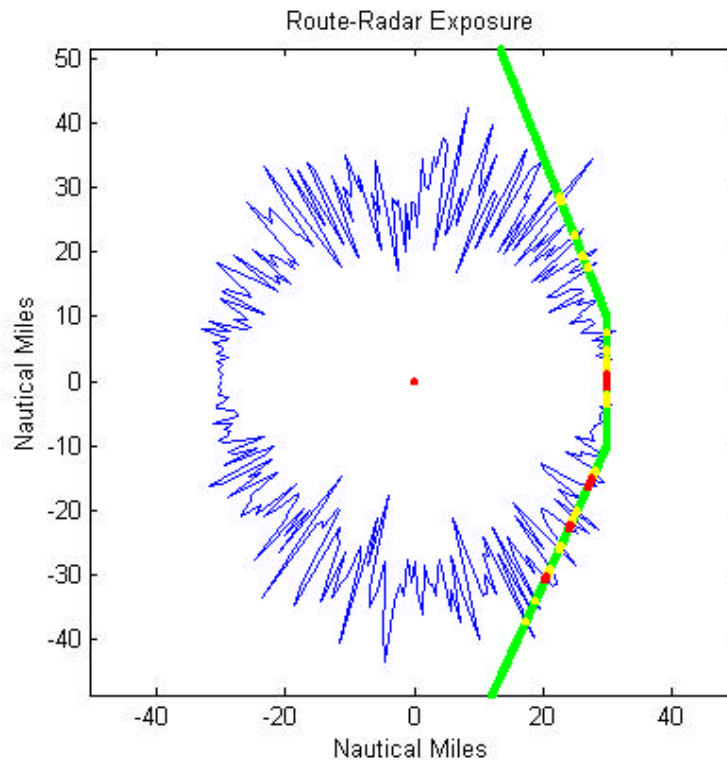

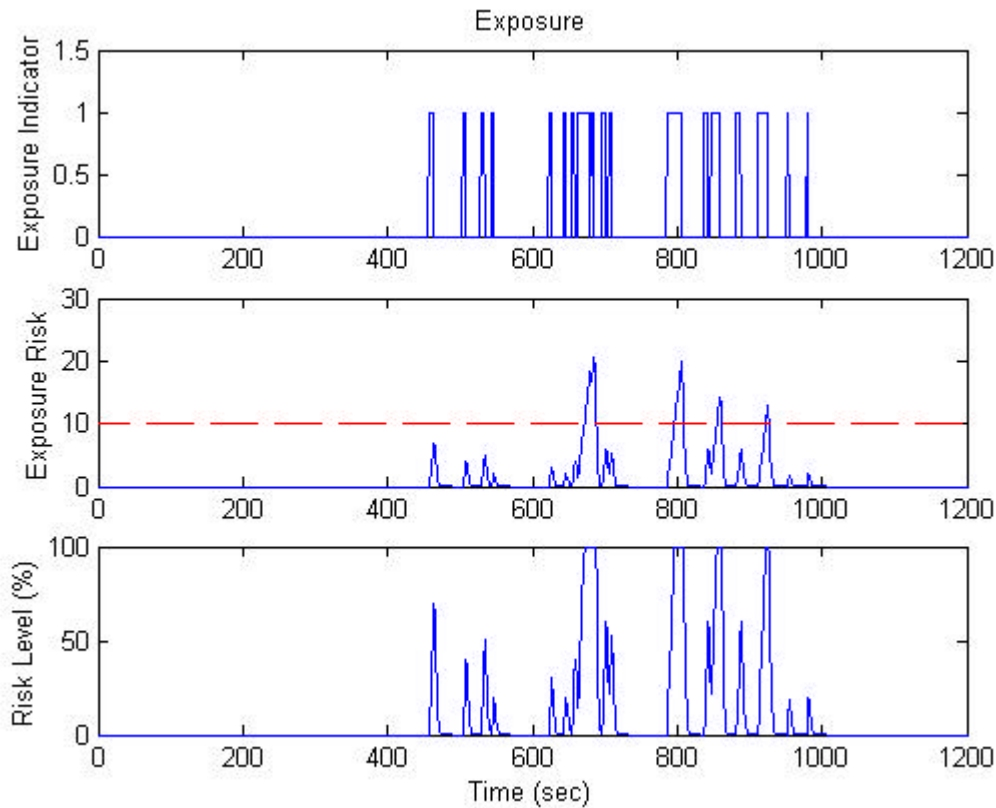*Figure 2. An example of risk assessment for a hypothetical route and a stationary template.*

Figure 3. (a) The time when the platform is within the threat range. (b) The evaluation of continuity where the dashed line represents the risk threshold (in seconds). (c) The normalized risk.

Once the exposure surpasses the risk threshold or, equivalently, the risk level hits 100% of allowable, then the RAVE engine can be used to trigger the dynamic asset reallocation optimizer. Additional risk parameters that will be incorporated in the future will include route deconfliction as well as status of the platform. Further work in assessing lethality of threats is being conducted in an attempt to quantify risk to strike assets (Wendt et al, 2001).

Dynamic Decision Support

A Dynamic Decision Support (DDS) tool is being developed to support the dynamic reallocation of strike force assets in theater. The objectives for the DDS tool include:
- Rapid weapon-target pairing options generation to Tasking Authority
- Provide automatic routing capability
- Dynamically reallocates assets based on high priority target trigger
- Dynamically reallocates assets based on changing environment

- Minimizes risk while maximizing effectiveness

The overarching goal of this DDS tool is to provide weapon-target pairing recommendations to a commander with tasking authority. The DDS tool can be triggered based on the insertion of a high priority target into the mission objectives. Nominally excessive risk levels of threats impinging on the blue force assets will trigger the DDS tool.

Recommendations are generated in a continuous manner to facilitate options generation at some time *T*. Weapon-target pairings do not constitute a complete solution. Route information, and the risk assessment of that route, must also come with any recommended weapon-target pairings to form a complete solution. These options are presented to the tasking authority for their modification and/or approval.

A tradeoff exists between maximizing mission effectiveness and minimizing overall risk to the mission. A slider that emphasizes the effectiveness/risk tradeoff is provided to the tasking authority to incorporate commander's intent into the optimization engine.

The optimization engine has been chosen based upon the need to support continuous options generation, direct search capabilities (so that the objective function is easily changed without affecting the search mechanics), and the potential to generate global solutions on a multimodal surface within a myriad of constraints. The optimizer chosen is based on evolutionary computation techniques augmented with case-based reasoning methods.

The optimization loop is shown in Figure 4. Once platforms are identified based on their availability and time to respond, they are allocated with the most effective munitions based on the Joint Munitions Effectiveness Manual (JMEMS). After allocations are made, routes are generated and risk assessed. The overall mission effectiveness and risk is then evaluated to complete the iteration.
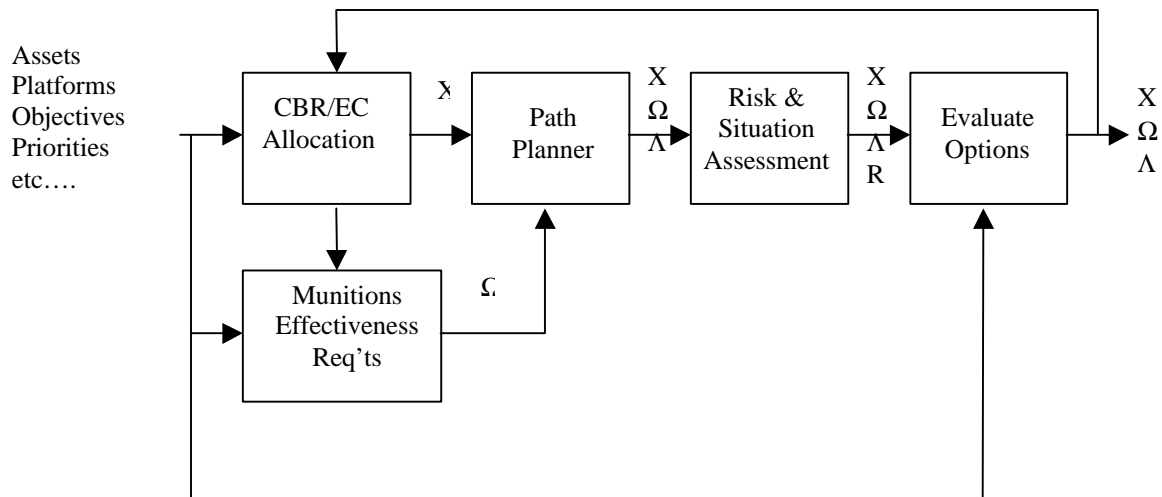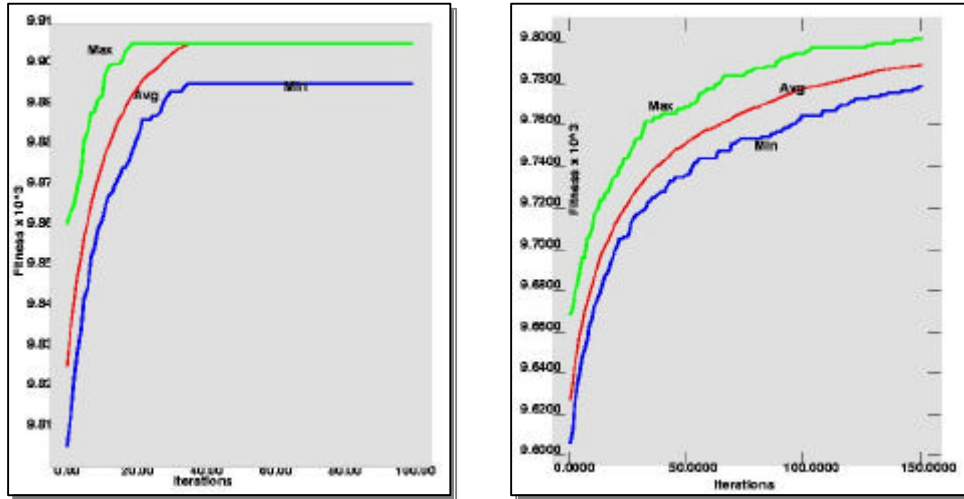

Figure 4. The iteration loop for optimizing strike force asset allocation.

(a)   *(b)*

Figure 5. (a) Genetic Algorithm performance on 10 platform – 10 target pairing problem; (b) Genetic Algorithm performance on 20 platform-20 target pairing problem.

The formulation for the strike asset optimization problem is given by McDonnell et al (2002). Preliminary studies have shown that the optimizer works rapidly for relatively small problem sets such as 10 platforms with 40 assets attacking 10 targets and 20 platforms with 80 assets attacking 20 targets. Performance results on these problem sets are shown below in Figure 5.

While the convergence speed of these results is encouraging, additional work needs to be done to address allocating assets in a dynamic environment. Namely, the coupled problem of weapon-target pairing and risk evaluation of the route warrants further consideration. The search problem is partitioned such that attack assets are only allocated to attack targets while SEAD assets are only allocated to SEAD targets. The coupled interaction between mission risk and effectiveness is contingent on how the SEAD assets are allocated and resolving this issue is key to generating a robust DDS tool.

REDS-DSS Architecture

The REDS-DSS architecture is built on a BEA Weblogic Enterprise backbone and employs EJBs and Java Messaging Service (JMS) components in communicating with other servers. The REDS-DSS architecture is composed of two primary servers: the KSA server and the Common Environment Definition server as shown in Figure 6.

The Common Environment Definition (CED) server manages tactical data feeds such as GCCS-M and TES-N to provide track and other information on entities within the common operational picture. The CED server supports the Common Environment Definition object that combines track information with capability and performance information of the entity. If the entity is a strike asset, then corresponding mission planning information may be pulled from the Element Level Planning (ELP) Server or
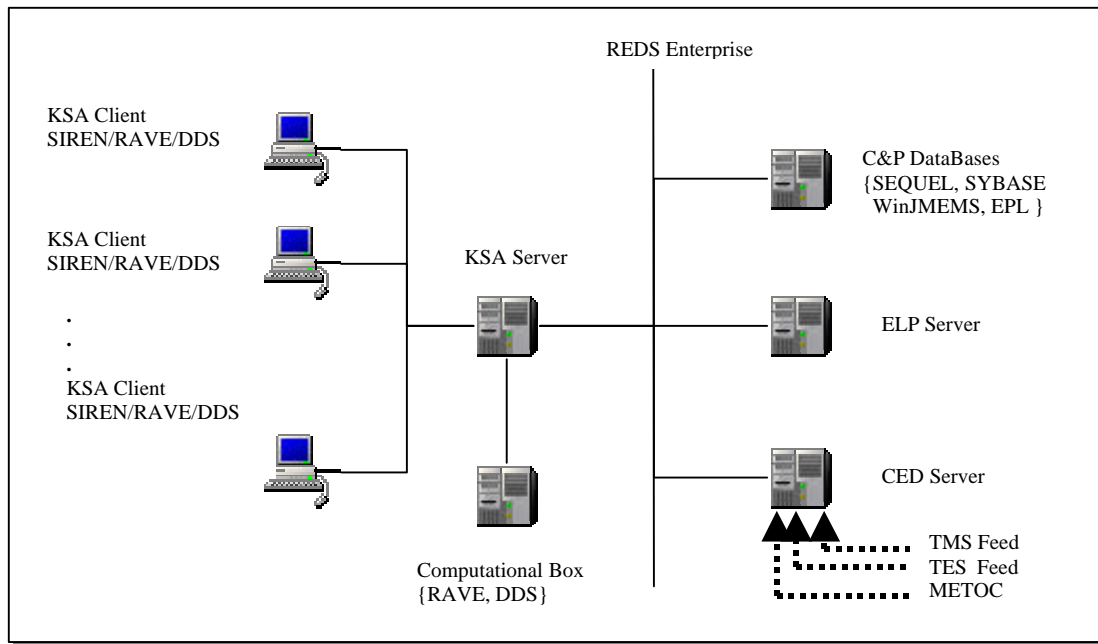
Figure 6. The REDS-DSS Architecture

through other mission planning servers. Software agents are used in support of strike planning activities for pulling METOC information in through the TEDS database.

The KSA server brokers the CED information to KSA clients. The risk assessment tool, RAVE, can be spawned as a backend process to provide continuous risk assessment to all blue force entities. Similarly, the dynamic decision tool is also launched as a backend process on a computational machine as needed by the user. These backend processes are transparent to the end user who is able to interact with the information with the KSA front end graphical user interface.

Conclusion

This work discusses the main components of the REDS-DSS tool for dynamically reallocating tactical air assets in particular and the strike force assets in general. While the situation assessment capabilities are readily realizable using tactical data feeds, work is underway to develop a comprehensive risk assessment tool. Additional work is being conducted in the context of dynamic resource allocation that accounts for SEAD and attack asset-objective pairings in conjunction with automated routing capabilities.

As the REDS-DSS tool matures in it's development, it will be necessary to instill a high level of confidence in the end-user. To achieve the desired confidence levels with the strike lead, simulations will be run and results evaluated and analyzed in the light of what constitutes an acceptable retargeting solution and what contributes to an unacceptable result.

The final product be able to rapidly generate options to the tasking authority that they can then use to retarget in-theatre assets. The tasking authority will be presented with a weapon-target pairings list that they can choose from before reallocating the strike teams. If no valid options are presented, the tasking authority can choose to modify any of the presented options or roll-back the team(s).

Acknowledgements

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